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F2A
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(54) Indicating wear in bearings

(57) A bearing for a moving member such as a propellor shaft of a ship comprises a bearing material (21) having a free surface (3), Fig. 4, for supporting the member as it moves and a wear detector (6). The wear detector is positioned at a predetermined depth below the free surface (3) and comprises a means of indicating when the bearing material has eroded down to said depth as a consequence of the movement of said member. The wear detector (6) may include a pair of conductors and a means of monitoring the electrical resistance across the conductors so as to detect a change in the resistance when the bearing material has eroded to that depth. Alternatively, the wear detector (6) may include a means (41) Fig. 7 for generating a beam of radiation and a means (42) of monitoring the beam, the beam being interrupted once the bearing material has eroded to said depth.

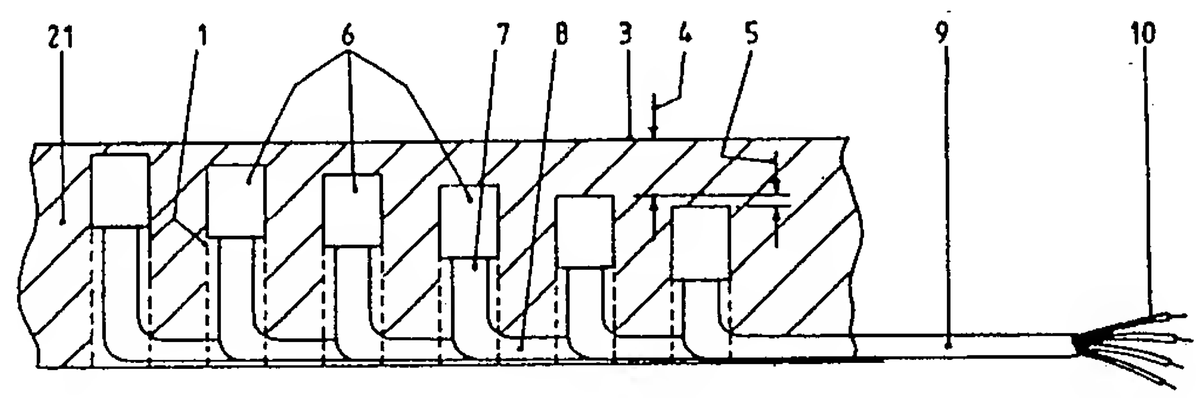

FIGURE 4

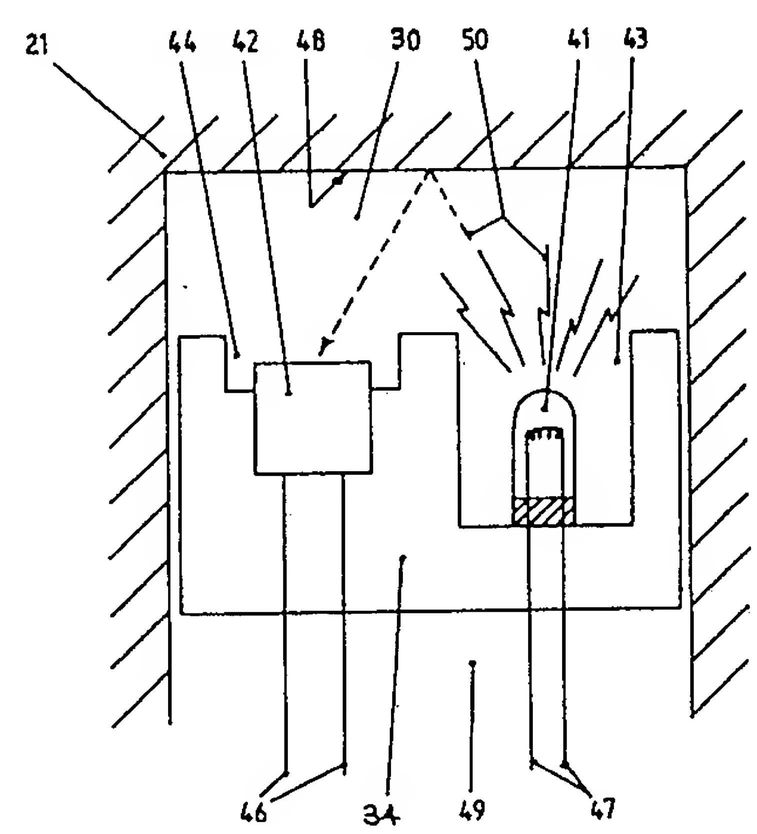

FIGURE 7

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The drawing(s) originally filed was/were informal and the print here reproduced is taken from a later filed formal copy.
The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

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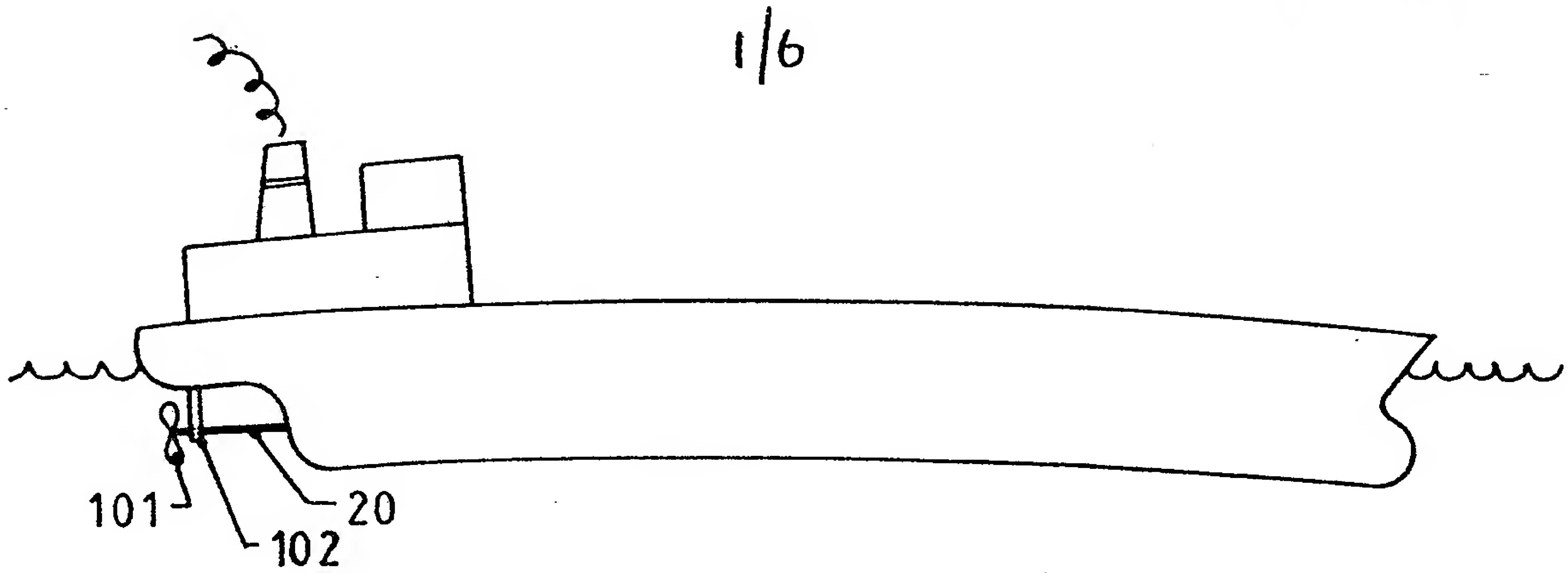

FIGURE 1:

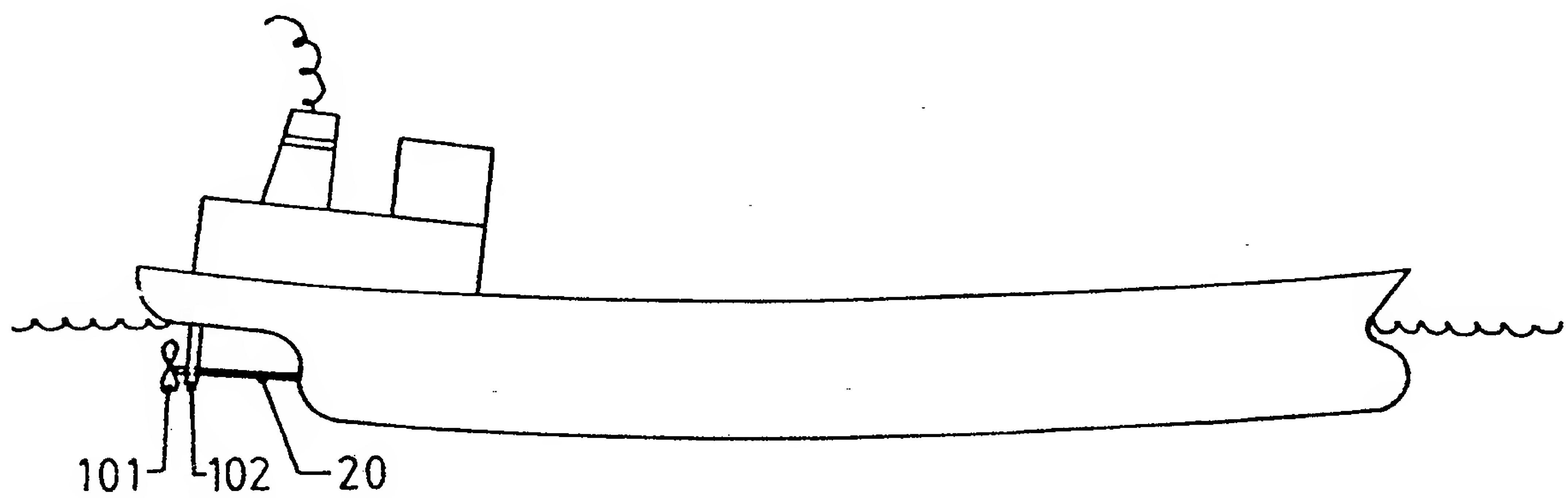

FIGURE 2:

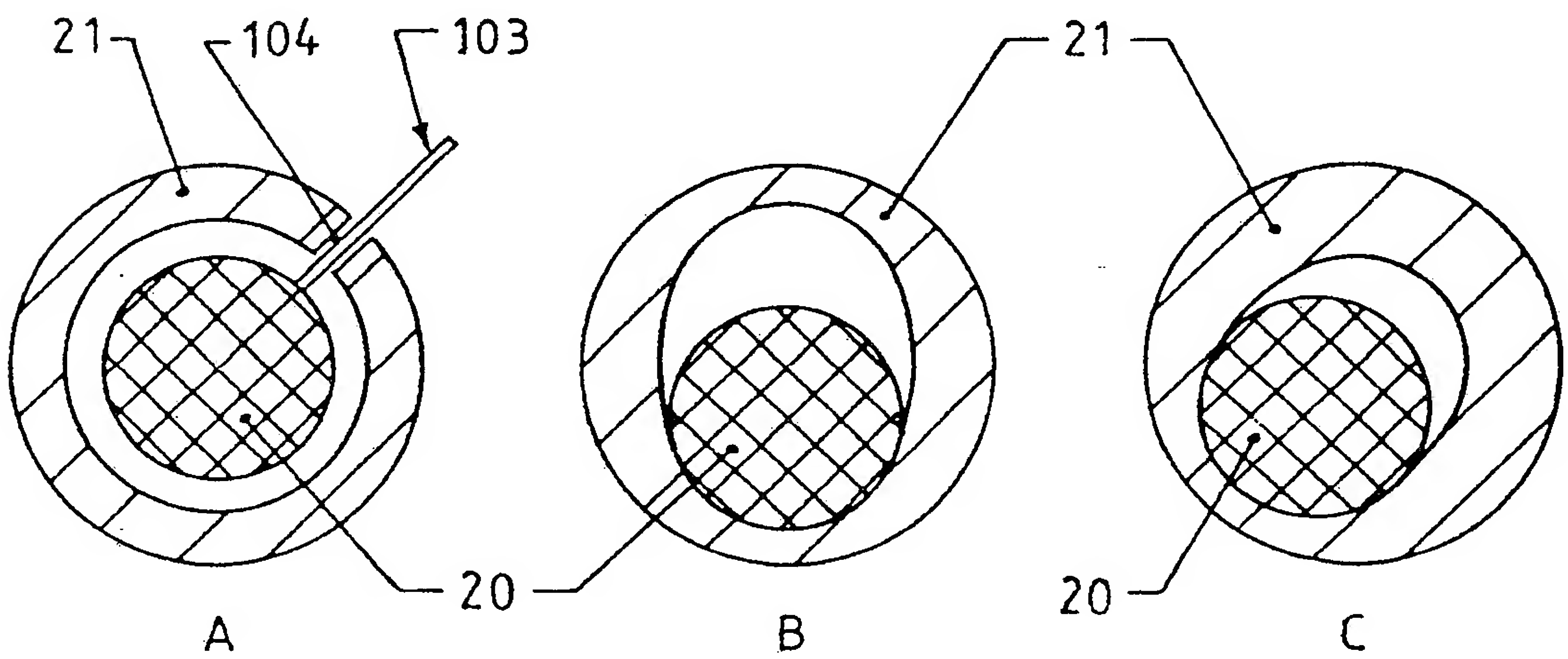

FIGURE 3:

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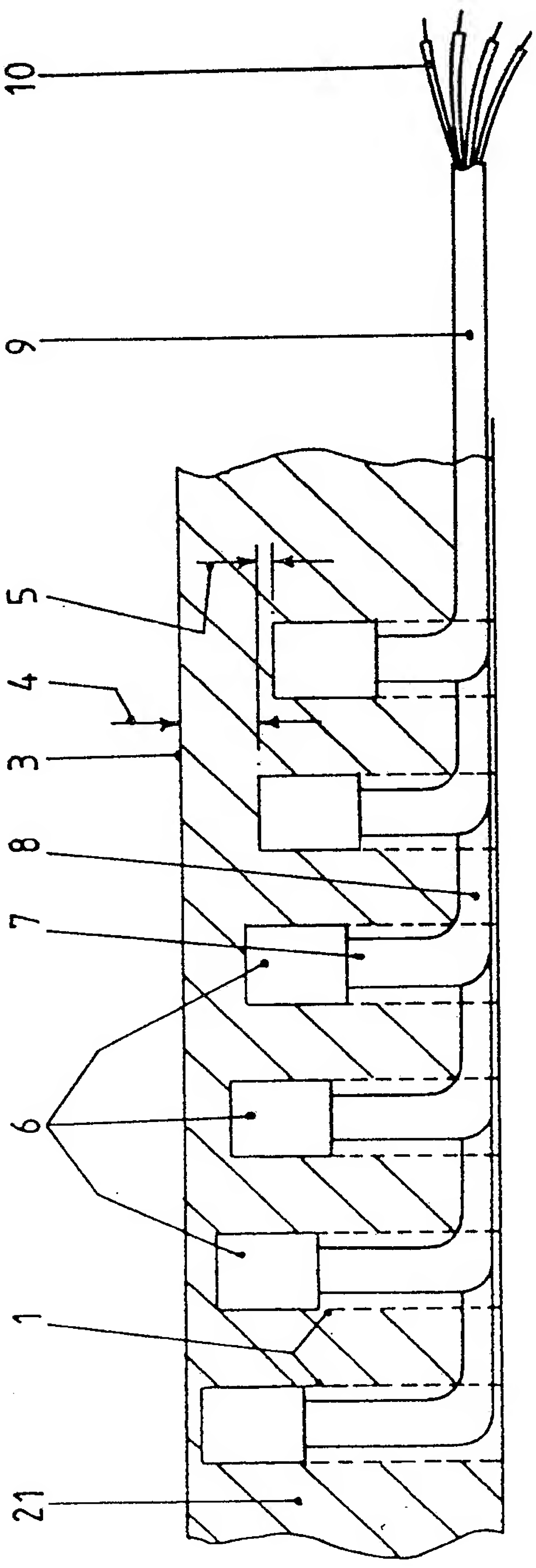

FIGURE 4

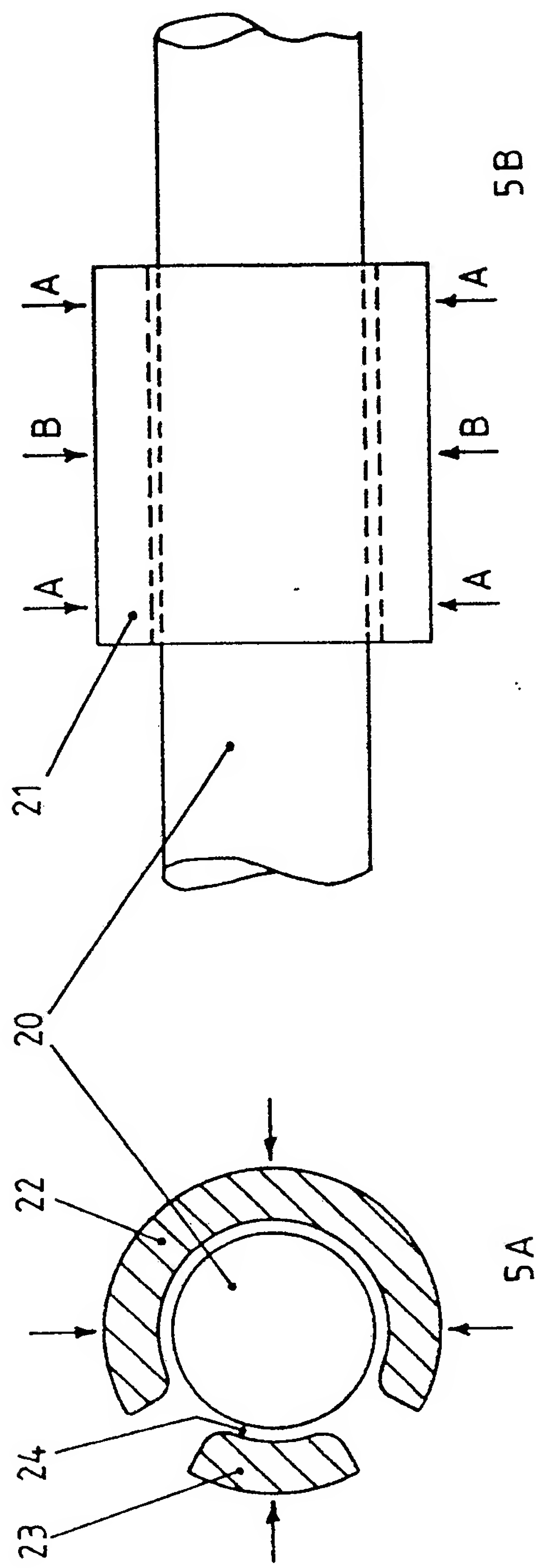

FIGURE 5

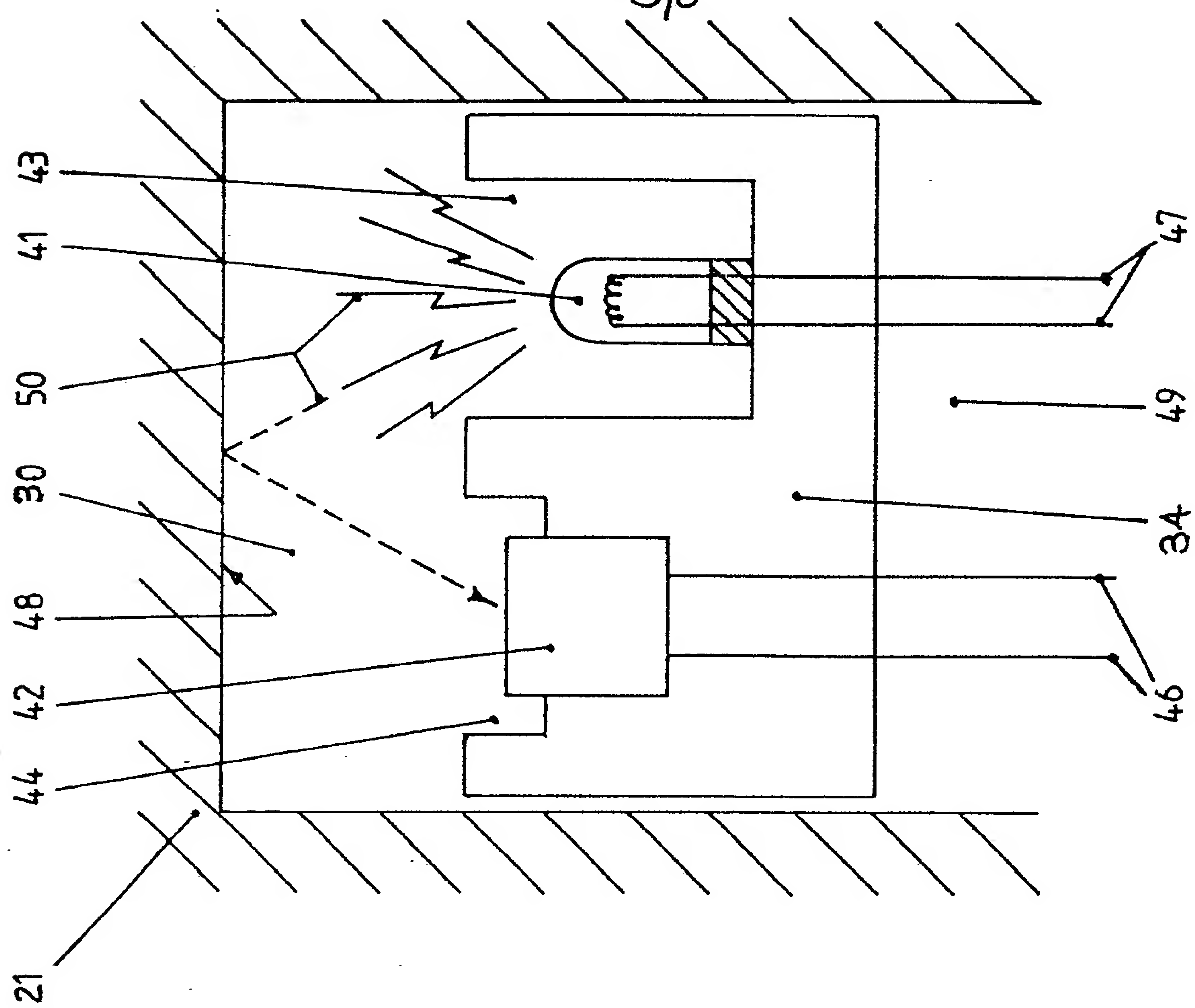

FIGURE 7

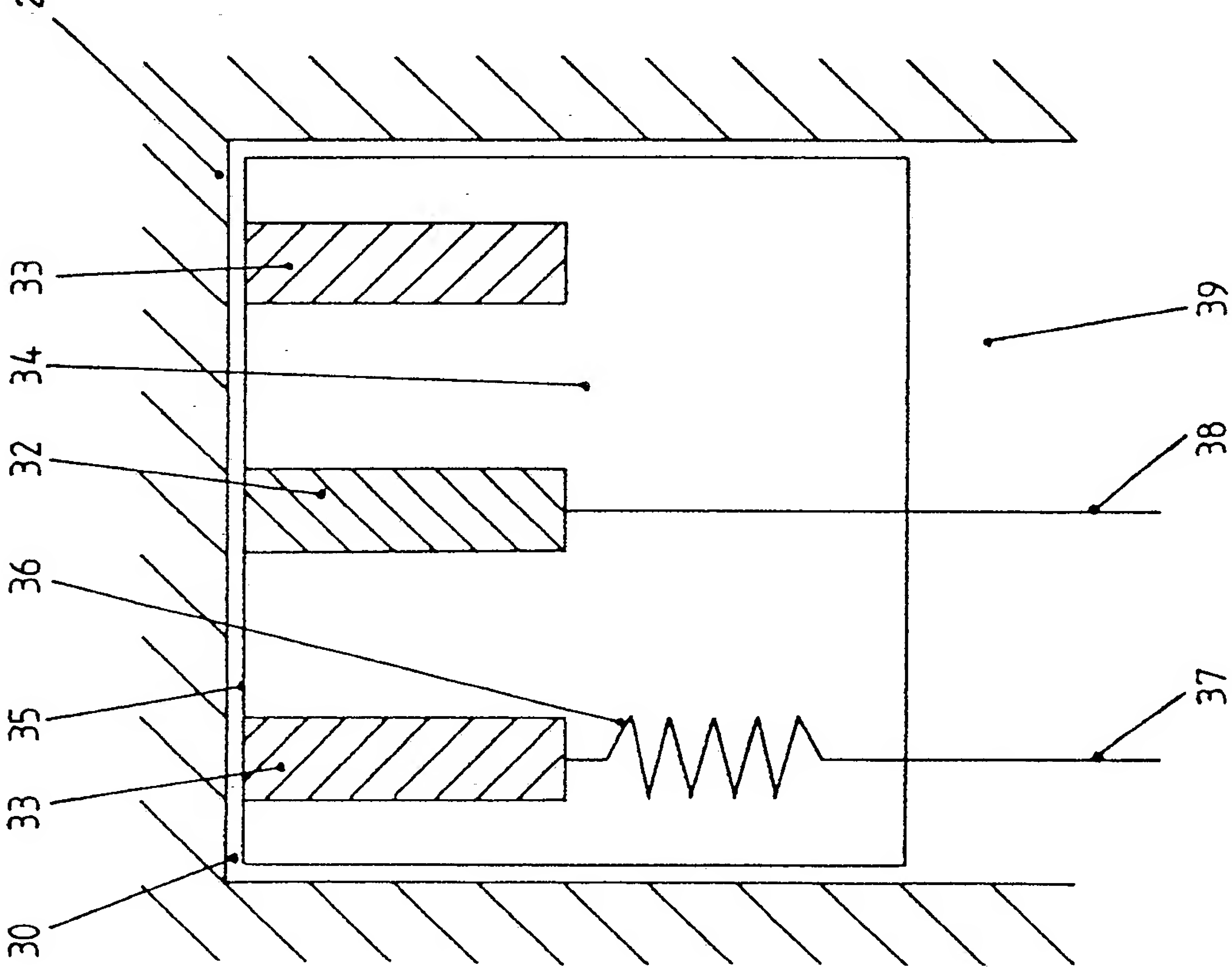

FIGURE 6

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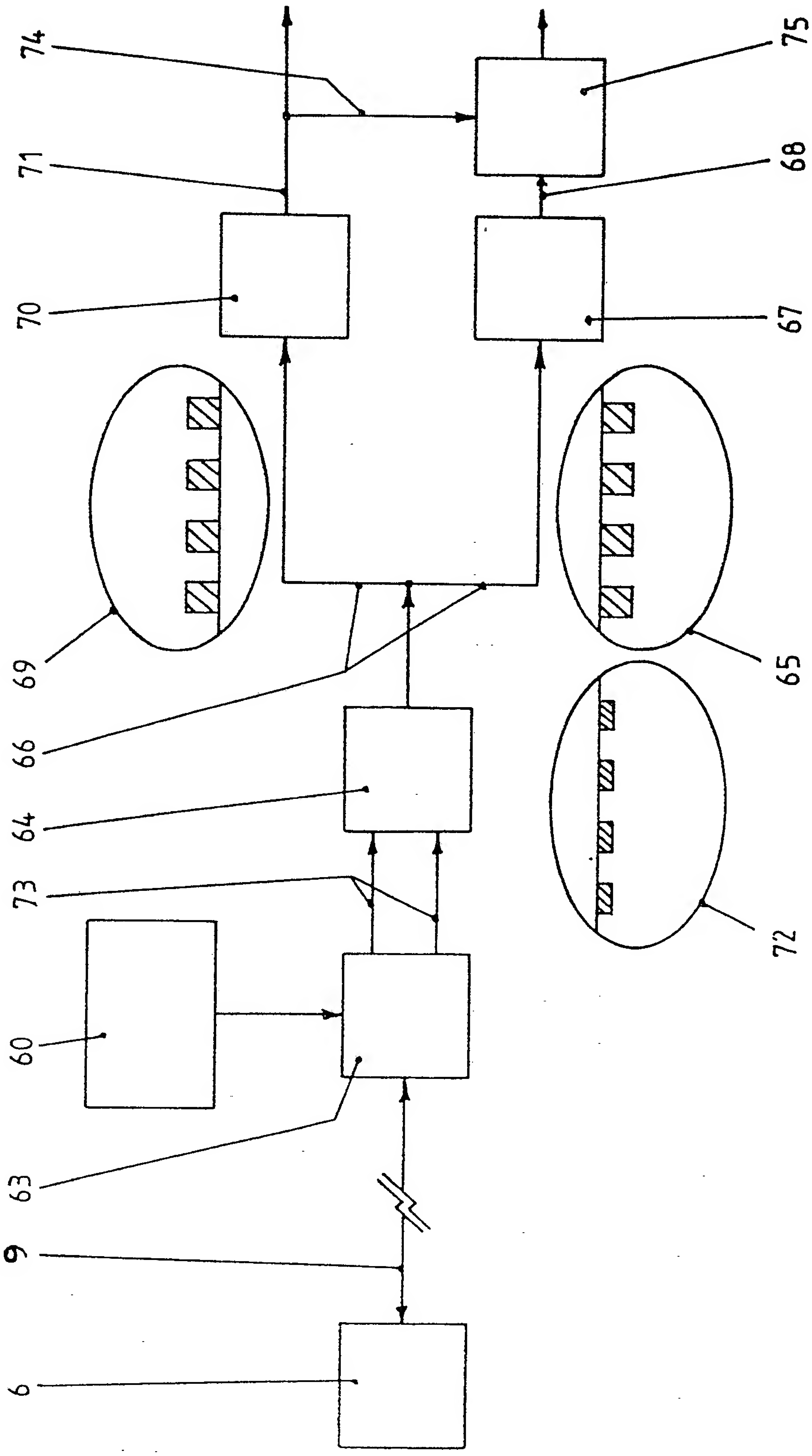

FIGURE 8

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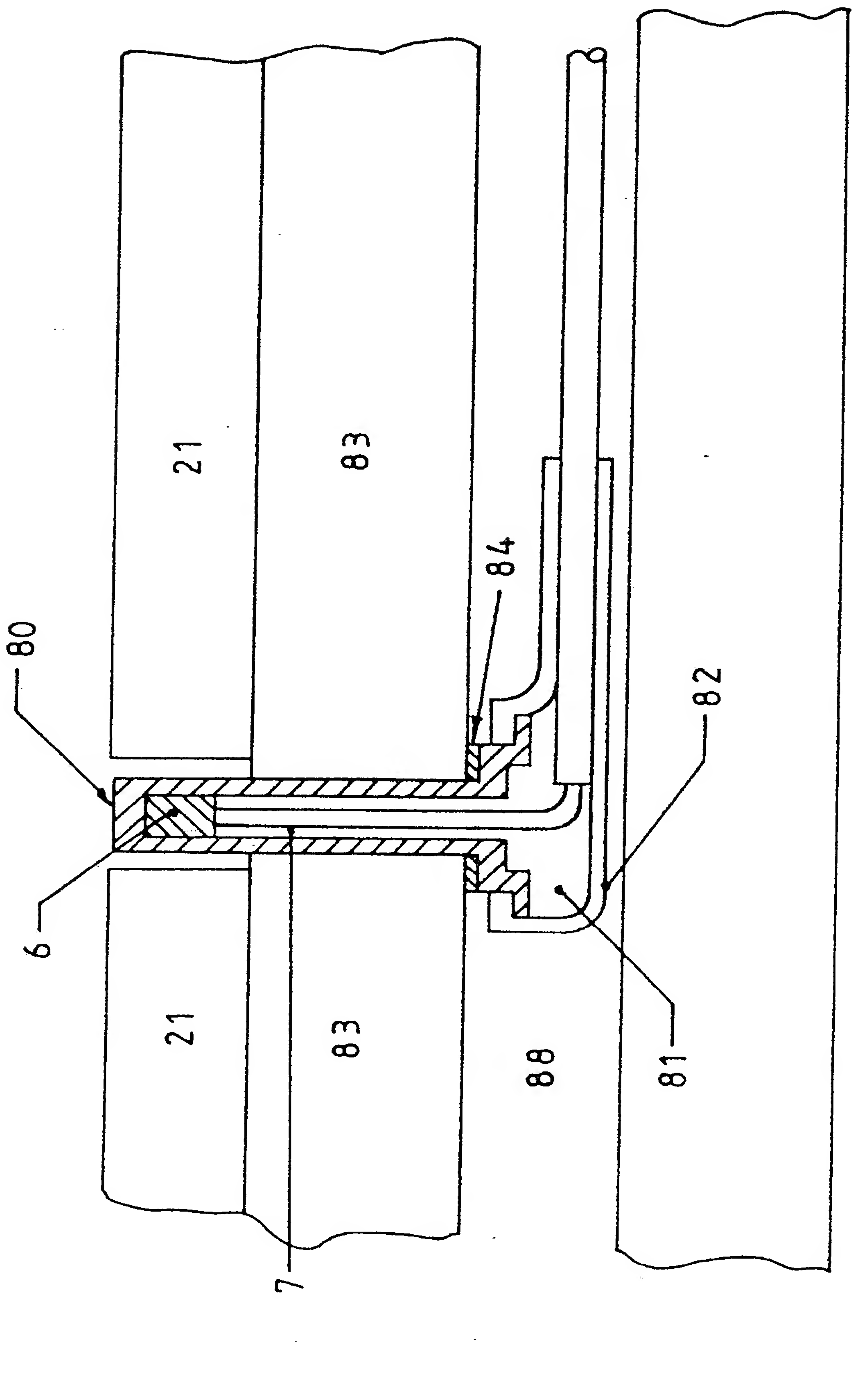

FIG. 9.

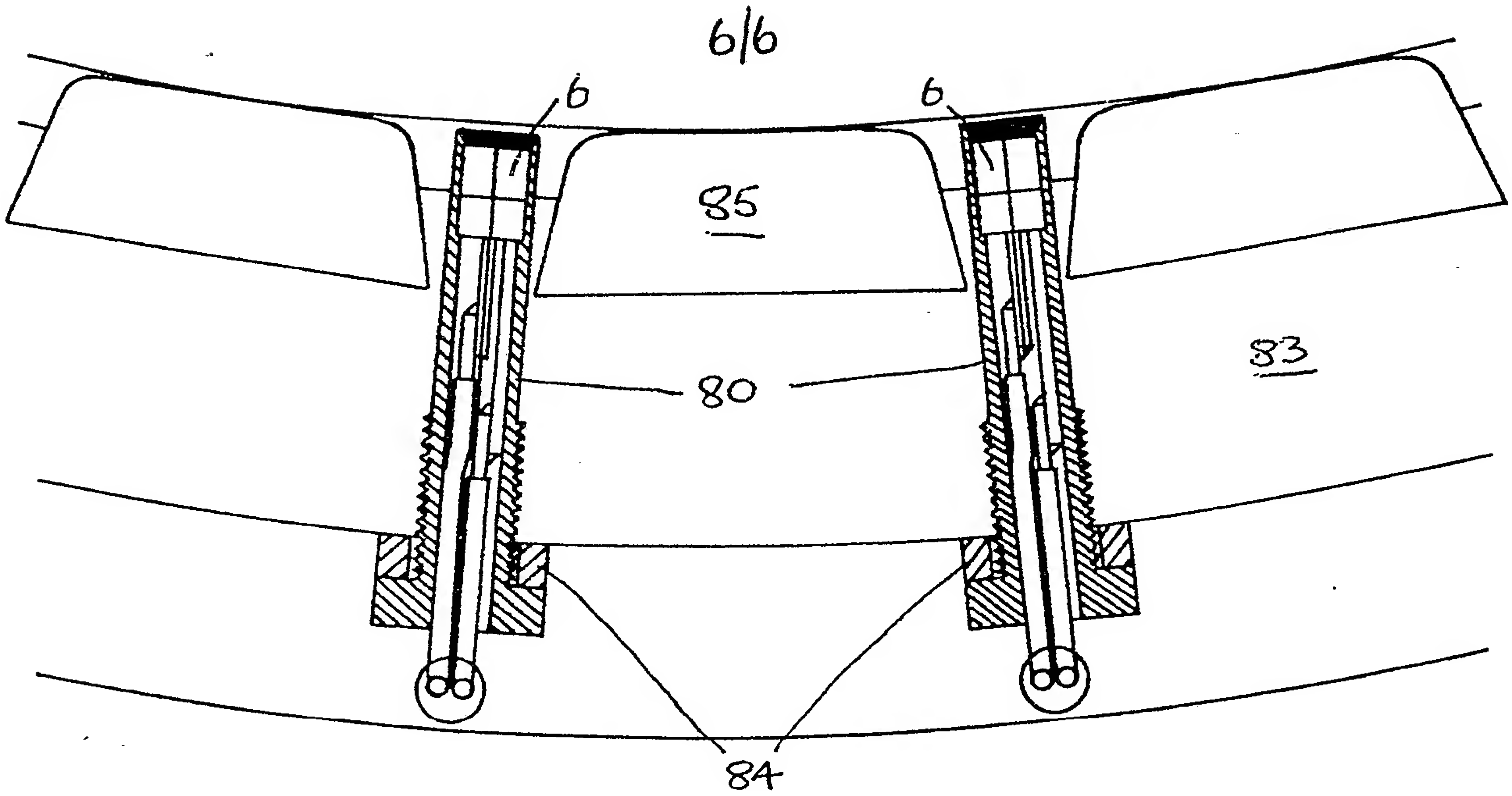

FIG. 10.

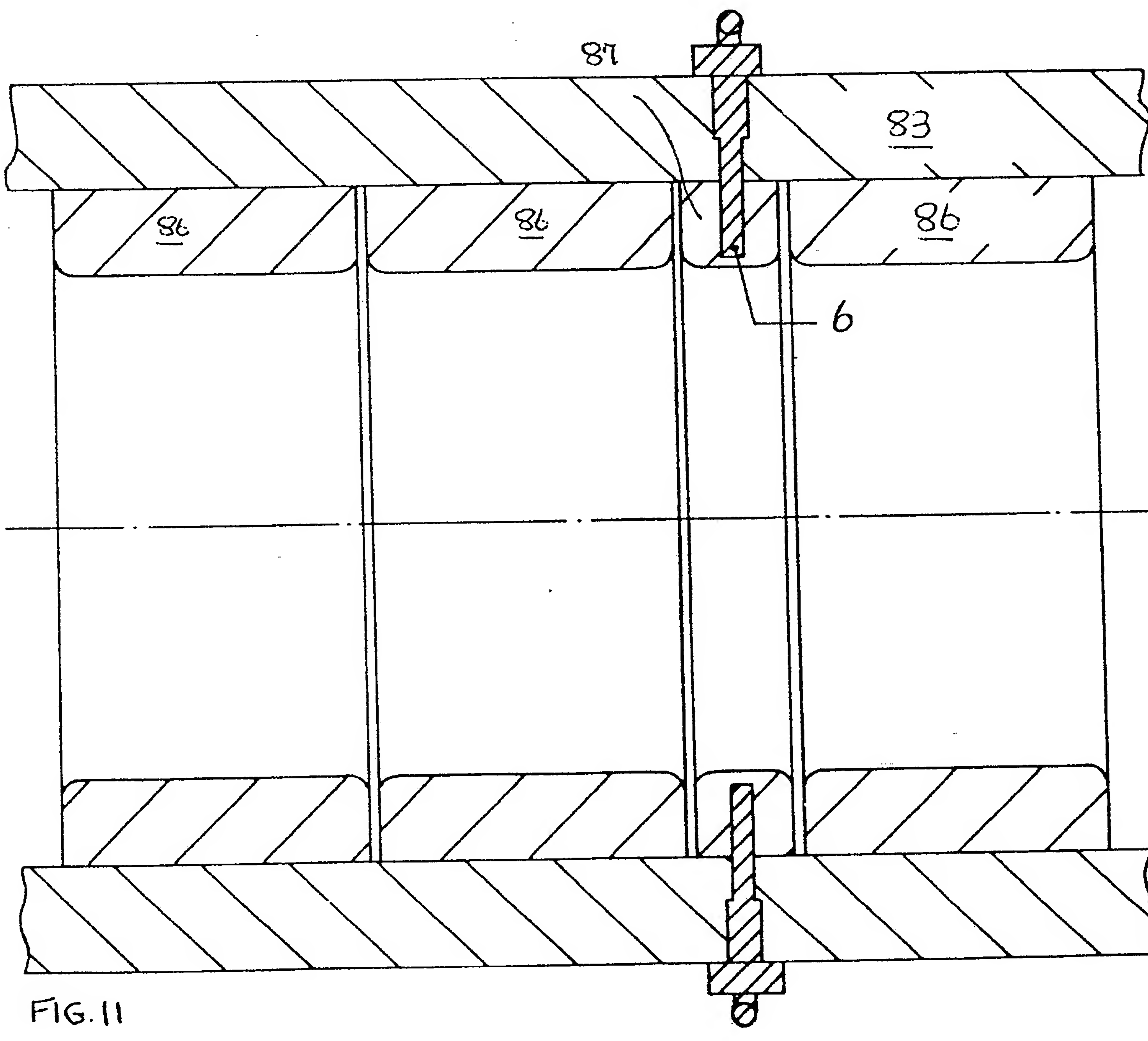

FIG. 11

SPECIFICATION

Bearings

This invention relates to bearings of the journal-type and more particularly, but not exclusively, is concerned with the stern propellor shaft bearings of ships.

The stern bearings of ships are usually of the water-lubricated journal type. The water for these bearings is extracted from the sea or river in which the ship is floating, filtered and pumped to the bearing. As a fairly large volume of water is used, the quality of filtration will normally be such that small particles of grit etc will be present in the filtrate. Thus the rate of wear of such bearings will be greater in silted water, especially if the water is saline, such as is found in estuaries, ports or near coastlines.

Further reasons for wear in these bearings are misalignment and the loading state of the ship. Figures 1 and 2 of the accompanying drawings show how the hull of a ship is flexible, causing it to 'hog' or 'sag' in different conditions. Hogging and sagging may be caused by either stormy weather or by the loading of the ship i.e. in dependence on whether the ship is fully laden, partly laden or in ballast. Furthermore, if the ship is 'yawing', there will be a tendency for the hull to twist about its longitudinal axis. In Figures 1 and 2, reference numerals 101,20 and 102 denote the propellor, propellor shaft and 'A' bracket respectively of the ship. In such a ship, the stern bearing is usually in the 'A' bracket. It is not difficult to comprehend how the effects of hogging and sagging place considerable additional loads on the stern bearing due to flexing of the hull.

Once a certain amount of wear has occurred in the stern bearing, the greater amount of freedom in the system will allow the amplitude of any vibrations present in the propellor shaft to increase. This could lead to 'whirling' or 'whipping' motions in the shaft which would rapidly erode the wearing surface of the bearing.

Figures 3 A, B and C of the accompanying drawings show sections through three journal bearings in "A" brackets. Each bearing includes a bearing material 21 having a hard wearing surface formed of, for example, a non-metallic resin or rubber-based material which supports propellor shaft 20. The water for lubrication is pumped under pressure into the annulus between the shaft 20 and the wearing surface of material 21. In Figure 3A, the shaft 20 and the wearing surface are concentric; wear has occurred but it is even. In Figure 3B, the effects of hogging and sagging, or whipping of the shaft, have led to excessive wear at the top and bottom of the wearing surface. In Figure 3C, all the wear has been concentrated in one quarter of the bearing.

At routine maintenance periods or other occasions, it is necessary to assess the mount of wear on the stern bearings. This is usually done by inserting a graduated probe 103 through a radial hole 104 in the bearing material until it touches the propellor shaft (Fig.3A) and reading off the graduation at the point where the probe enters the hole. As is apparent from Figures 3B and 3C, this could give very misleading readings. Also, if the ship was in the water, as is usually the case, the work must be done by a diver. Thus present methods of measuring stern bearing wear are expensive, difficult, unreliable and can be performed only in selected locations. Hence there is a need for a cheap, accurate, in situ method of monitoring the rate of wear which will show whether that wear is uniform or irregular.

According to the present invention there is provided a bearing for a moving member, such as a stern propellor shaft of a ship, which bearing comprises

(i) a bearing material having a free surface for supporting the moving member and

(ii) a wear detector for detecting when the bearing material has worn to a predetermined extent, said wear detector being positioned at a pre-determined depth below said surface, and comprising a means of indicating when the bearing material has eroded down to said depth as a consequence of the movement of said member.

In a first embodiment of the invention, the wear detector includes a pair of conductors and monitors the electrical resistance across the conductors. The arrangement is such that the resistance changes once the bearing material has eroded to said depth and the change in resistance produces a measurable signal. In this case the two conductors may be adjacent, or concentric, with respect to one another and may be mounted in a non-conducting matrix to form a unit which is located in a blind hole in the bearing material. One of said conductors is connected to a high electrical resistance and hence to one end of a first electrically conducting wire and the other of said conductors is connected to one end of a second electrically conducting wire. The first and second electrically conducting wires are connected at their other ends to an electrical monitoring means such that erosion of the surface of the bearing material down to said predetermined depth will expose said wear-down detector allowing electrical continuity to be established between the conductors either by contact with the lubricant, if said lubricant is an electrolyte, or by direct contact with the moving member. This electrical continuity enables said electrical monitoring means to signal the fact that said bearing material has been eroded to said predetermined depth. Preferably the electrical monitoring means is such

as to be able to recognise the presence of fault conditions.

In a second embodiment of the invention, the wear detector includes a means of generating a beam of radiation and monitors the beam. The arrangement is such that the beam is interrupted once the bearing material has eroded to said depth. In this case the wear detector may comprise

(i) a means of emitting a suitable form of radiation essentially in a single direction (i.e. the radiation is projected in a small solid angle);

(ii) a means of detecting said radiation, the detecting means being shielded so that there is no direct line of sight to the emitting means;

(iii) an essentially flat surface spaced a short distance away from the emitting means and the detecting means and capable of reflecting, or absorbing and re-radiating, said radiation from the emitting means and towards the detecting means; and

(iv) a means of recording whether said detecting means is, or is not, registering the presence of said radiation incident upon it.

Preferably the emitting means and the detecting means are mounted side by side, in shielded recesses, in a suitable matrix to form a unit, which may be mounted in, but not right at the end of, a blind hole in the bearing material. The blind end of the hole constitutes the essentially flat surface and preferably the hole is made from the reverse side of the bearing material towards the free surface of the bearing material such that the blind end of the hole is at a predetermined distance from, and approximately parallel to, said wearing surface.

It is not essential that the blind hole containing the wear detector be perpendicular to the free surface of the bearing material but this is strongly preferred. It is however possible for the blind hole to be angled, or even nearly parallel to the free surface. In such cases, when the bearing material is worn down to expose part of the hole, the lubricant will enter the hole and either short the conductors (first embodiment) or absorb the radiation (second embodiment) and cause the wear state to be registered in each case.

Preferably a plurality of weardown detectors will be used in groups or sets with each detector located at a different depth so that it is possible to monitor progressively, and in an incremental manner, the rate of wear of the bearing material. The or each detector may be embedded in the bearing material or be mounted adjacent to the bearing material, e.g. alongside, or between adjacent parts of a multi-element bearing. Preferably each detector of each group or set is interrogated in turn so that a complete picture of the bearing wear can be established.

For a better understanding of the invention and to show how the same may be carried into effect reference will now be made by way of example to the accompanying drawings, in which:

Figure 1 is a diagrammatic illustration of a ship 'hogging',

Figure 2 is a diagrammatic illustration of the ship of Figure 1 'sagging',

Figures 3A, 3B and 3C show sections through water-lubricated stern bearings in the 'A' brackets of ships,

Figure 4 is an axial section through a part of a bearing of the invention showing the position of one set of weardown detectors,

Figure 5A is a cross-section through a part of a bearing of the invention showing the positions of a plurality of sets of weardown detectors,

Figure 5B is an elevation of a bearing of the invention showing other positions of a plurality of sets of weardown detectors,

Figure 6 is a partial cross-section through a part of a first embodiment of a bearing of the invention,

Figure 7 is a partial cross-section through a part of a second embodiment of a bearing of the invention,

Figure 8 is a block diagram illustrating the monitoring circuitry of the bearing of Figure 7,

Figure 9 is a partially sectioned view of a bearing of the invention showing an alternative mounting of the weardown detector,

Figure 10 is a radial section through a part of a segmented bearing of the invention showing weardown detectors inserted through the bearing carrier into spaces between adjacent segments of bearing material, and

Figure 11 is a longitudinal section through a multi-element bearing of the invention showing the incorporation of weardown detectors into a ring of bearing material.

Throughout the drawings, corresponding parts are denoted by like reference numerals.

The basic principle of a hydrodynamic stern bearing is shown in Figures 5A and 5B. The bearing includes bearing material 21 which is suitably supported in an A bracket, or other equivalent structure (not shown) and has an inner cylindrical surface. The propellor shaft 20 passes coaxially through the bearing material to define an annulus 24 therebetween. The bearing material may be either continuous (as denoted by reference numeral 22 in Figure 5A) or in segmented sections (as denoted by reference numeral 23 in Figure 5A). Water under high pressure is pumped into the annulus 24 to give hydrodynamic lubrication as the shaft 20 rotates.

Figure 4 shows a section through the bearing material 21 (which may be continuous or segmented as above described) and a set of weardown detectors within it. A plurality of blind holes 1 is carefully drilled in the bearing material 21. Each hole 1 is drilled through the rear face of the material 21 towards free sur-

face 3 of the bearing material, but stops short of surface 3 by a predetermined distance (for example as denoted by reference numeral 4). As shown in Figure 4, the predetermined distance increases from left to right with each successive hole 1 being further from the free surface 3 by a differential distance 5. In a practical situation, the predetermined distance between the closed end of the hole 1 at the extreme left and the free surface 3, may be, say, 2.0 mm and the differential distance 5 may be say 0.5 mm. In this case the predetermined distances for the six holes 1 shown in the Figure would be 2.0, 2.5. 3.0, 3.5, 4.0 and 4.5 mm from left to right respectively. Thus, as free surface 3 is worn away by the rotational motion of the propellor shaft, each hole 1 will be progressively exposed.

A weardown detector 6 is inserted into each hole 1 and the connecting leads 7 are all taken away through a groove 8 cut into the rear face of bearing material 21. The leads 7 are taken *via* screened cable 9 in suitable ducting (not shown) into the ship where the individual conductors 10 of the cable 9 may be connected to the detection circuitry (Figure 8). Other arrangements for mounting the weardown detectors 6 and leading the conductors to the detection circuitry (Figure 8) are shown in Figures 9—11.

Before the nature of the weardown detectors 6 is described, the conditions under which they are to operate will be considered. Figure 1 shows the proximity of the A bracket 102 (where the stern bearing is located) to the propellor 101. Due to the overhung load of the propellor 101 on the propellor shaft 20, the distance between the propellor 101 and A bracket 102 should be as small as possible, consistent with hydrodynamic considerations. Thus the stern bearing weardown detectors 6 and connecting cabling 9 will be subject to:

i) high water velocity

ii) the abrasive effect of entrained particles

iii) corrosive environment

iv) vibration induced by the flow of water

v) high pressure due to the hydrodynamic wedge built up between the rotating propellor shaft 20 and the free surface 3 of the bearing material

vi) pressure cycling

vii) shock loading due to ship motions, wave slam etc.

viii) temperature variation from −2 to +35°C, and

ix) microbial action due to marine organisms.

Moreover, it has to be borne in mind that, in a hydrodynamic bearing, the shaft will not ordinarily touch the free surface of the bearing material due to the effect of the pressure wedge of the lubricant during operation and, in the case where the measurement of weardown is made intermittently in port, the propellor shaft will not necessarily touch the free surface at the point of maximum weardown (see Fig.3) depending upon the loading state of the ship. Thus, the weardown detectors need to be capable of operating in such circumstances.

Figure 6 shows a first embodiment of the invention. A flat-bottomed blind hole 30 is drilled in the bearing material 21 so that the closed end of the hole 30 is a precise distance 4 (Figure 4) from the virgin surface 3 of the bearing material. A weardown detector is mounted in hole 30. It includes a unit comprising central and annular graphite terminals 32 and 33 respectively, mounted in a suitable non-conducting matrix 34. The detector has an upper surface 35 which is polished after the matrix 34 has solidified so that the upper surfaces of both terminals 32 and 33 are clean. Embedded in the matrix 34 is a high value electrical resistor 35 which connects one of the terminals 32 or 33 (in this case annular terminal 33) to a first electrically conducting wire 37. The other terminal 32 is connected to a second electrically conducting wire 38. When the weardown detector has been inserted into the hole 30 and the electrical checks have been completed, space 39 may be filled with a suitable non-conducting matrix. Graphite is chosen for terminals 32 and 33 because it and the material of non-conducting matrix 34 are softer than the bearing material 21 and thus would never cause scoring of the propellor shaft. Other soft conducting materials are equally suitable. The axial length of terminals 32 and 33 may be chosen for each particular application, but it is preferred that they are sufficiently long to keep sending signals as the other detectors in that set (Fig.4) are exposed.

A second embodiment is shown in Figure 7. In this case the wear detector comprises an infrared emitting diode 41 and an infra red detector 42. As in the case of Figure 6, the detector is embedded in non-conducting matrix 34 to form a unit which is located in blind hole 30. Both diode 41 and detector 42 are situated in recesses 43 and 44 respectively so that there is no direct line of sight from one to the other. When the detector has been installed in the hole 30, at a suitable distance from closed end 48, and electrical connections 46 and 47 have been tested, space 49 may be filled with a non-conducting matrix.

The weardown detectors as shown in Figure 4 may be of the type shown in Figure 6 or 7. In use, gradual wear of the free surface 3 will progressively expose each detector to the presence of sea water (or lake or river water where appropriate). In the case of detectors of the first type (Figure 6), on exposure of each detector, a small current will pass through the impure water and this can be detected as will be described later. In the case of detectors of the second type (Figure 7) infra red radiation 50 from diode 41 will

reflect off closed end 48 and will be detected by detector 42. However once the wear has reached the stage at which the closed end 48 has been removed, no reflection will occur and detector 42 will cease to register the presence of infra red radiation.

In practice, as shown in Figures 3B and 3C, bearing wear often occurs irregularly. Thus to be able to monitor the wear with confidence, several sets of weardown detectors (i.e. as shown in Figure 4) will be needed. A basic arrangement of four sets of detectors at 90° intervals, should ordinarily be adequate, i.e. in line with the arrows in Figure 5A. In most cases, a single arrangement of four detectors around the middle circumference of the bearing should be adequate, i.e. as shown by arrows B in Figure 5B. In some cases however, there is a tendency that, when propellor shaft 20 is rotating, its axis may not be coaxial with that of the bearing material 21. In such cases, it may be desirable to have one or more further sets of detectors in line with one or more of arrows A (Figure 5B). It will be apparent to the man skilled in the art that the number and positions of the sets of weardown detectors may be specified individually for each propellor shaft and A bracket from a knowledge of the bearing's particular characteristics as shown by the wear pattern of the bearing previously fitted. Also the relative distances 4 and 5 (Figure 4) may be determined according to the nature of the vessel, e.g. merchant ship, passenger ship, warship etc.

Figure 8 shows in block diagram form how sets of weardown detectors of the type shown in Figure 6 can be interrogated to determine the state of bearing wear. It will be understood that the monitoring of the bearing wear could be done on a continuous basis or at specified regular intervals, e.g. hourly, daily, etc. If there was cause for concern, the time intervals could be reduced.

A microprocessor (not shown) would be provided to systematically connect each detector in each set to the monitoring circuitry (Figure 8). The monitoring circuitry is capable of distinguishing three different cases i.e.:

i) wear has not reached the detector

ii) wear has reached the detector

iii) a fault condition was present The circuitry includes an oscillator 60 which supplies power as a series of pulses to each wear down detector 6 *via* the screened cable 9. The detector 6 and cable 9 form one arm of a bridge circuit 63. The output from the bridge circuit 63 is shown as two parts 73. One part represents the input pulse after passing through a resistor of known value and the other part represents the pulse after passing through the detector 6. Differential amplifier 64 detects the change in polarity between these two parts 73 and amplifies it.

There are three possible outputs from the differential amplifier 64. Firstly, if the detector 6 has not been exposed as a result of bearing wear there will be only dry air between terminals 32 and 33 which will give effectively an open circuit, i.e. an infinite resistance. This will result in a series of large negative pulses, as shown by reference numeral 65. This indicates a normal condition.

Secondly, if the detector 6 has been exposed as a result of bearing wear, the resistance measured by bridge 63 will be around 50k ohms. This will result in the output from amplifier 64 being a series of small negative pulses, as shown by reference numeral 72. The exact magnitude of these pulses 72 will depend on the electrical conductivity of the water e.g. sea water, river water, etc.

The third output is that due to a fault condition, when a conductor 10 of cable 9 has been damaged. In this case, resistance 36 will have been shorted so that the resistance measured by bridge 63 will be 5k ohms (or less). This will reverse the polarity in amplifier 64 and cause an output of large positive pulses, as shown by reference numeral 69.

The output from amplifier 64 passes into wiring 66. Here a valid signal monitor 67 will recognise only small negative pulses 72, i.e. an output of the second type. When such an output is detected a signal 68 will be produced to indicate that weardown has occurred to the level of that particular sensor. Fault detector 70 will react only to large positive pulses; when such pulses 69 are detected, it will cause a fault condition signal 71 to be produced. The fault condition signal 71 will also pass *via* connection 74 to a disabling circuit 75 which will override any valid signal 68 indicating wear. This is a further safeguard to ensure that a fault condition is recognised as such. The signal 68 from the valid signal detector 67 cannot pass along connection 74 so that no fault signal 71 can be recorded from this source. Neither fault detector 70 nor valid signal detector 67 will react to large negative pulses. Test circuitry is built in (but not shown) to check the detectors in their normal passive condition, i.e. when not exposed. Conventional test circuitry is built in to check that both detectors 67 and 70 and other parts of the monitoring circuitry are functioning correctly.

In the case where weardown detectors of the type shown in Figure 7 are used a signal would be received from the infra red detector 42 if infra red radiation 50 is reflected from the closed end 48, i.e. if weardown had not reached that point. When closed end 48 has been worn away, no radiation 50 will be reflected or detected and no signal will be produced. This indicates weardown at that point. Damage to electrical connections 46 and 47 would not be detectable since a fault with this type of detector would cause no signal to be returned via connections 46. The existence of a fault could sometimes be in-

ferred from the evidence given by other detectors in the set. When the signal from this type of detector ceased, the fact would be recorded and the power supply would be cut off.

Though a linear arrangement of weardown detectors is shown in Figure 4, for clarity, it will be understood that any suitable arrangement is possible e.g. circumferentially round the bearing, or in triangular or square patterns, etc.

Referring now to Figure 9 there is shown an alternative manner of mounting the weardown detectors. In this case, the detector 6 is inserted in a cylindrical waterproof sheath 80. The sheath may be machined out of a solid material or cast around the detector. The wires 7 leading from the detector are encased in a suitable matrix 81 e.g. epoxy resin, and the whole sealed by a waterproof membrane 82. A standard size of weardown detector can be produced and mounted by inserting it through holes in the bearing material 21 and its associated bearing carrier 83 as shown in Figure 9. Washers 84 of different thickness may be used to vary progressively the preset depths of the detectors below the free surface of the virgin bearing material, in the fashion described previously with reference to Figure 4. It will be understood that the material from which the sheath is constructed would be mechanically softer than that of the bearing material.

The weardown detectors may be secured in position in the holes by screw threads, as shown in Figure 10, or by any other suitable method, e.g. gluing, etc.

Weardown detectors mounted as shown in Figure 9 could be located in gaps between individual bearing elements forming a complete bearing. For example, in the case where the bearing consists of a plurality of bearing elements 86 (as shown in Figure 11 where the elements 86 may be either segmented or continuous), the weardown detectors may be mounted between adjacent bearing elements. Alternatively a narrower bearing element 87 may be produced for the specific purpose of housing the weardown detector 6, as shown in Figure 11.

One of the advantages of the mounting methods shown in Figures 9, 10 and 11 is that the bearing is not weakened by the need to cut a groove 8 (Fig.4) for the leads 7. A further advantage is that by taking the leads 7 through the bearing carrier 83 into the tallow space 88 (i.e. to an area where mechanical loadings will be less), there will be a reduced risk of damage to the individual conductors 10.

It will be apparent to the man skilled in the art that there are other types of detector which could fulfil the required duty and other variations of the mounting arrangements disclosed herein which could be used, all falling within the scope of the invention described hereinbefore.

CLAIMS

1. A bearing for a moving member, which bearing comprises

(i) a bearing material having a free surface for supporting the moving member and

(ii) a wear detector for detecting when the bearing material has worn to a predetermined extent, said wear detector being positioned at a predetermined depth below said surface, and comprising a means of indicating when the bearing material has eroded down to said depth as a consequence of the movement of said member.

2. A bearing as claimed in claim 1 wherein the wear detector includes a pair of conductors and monitors the electrical resistance across the conductors, the arrangement being such that the resistance changes once the bearing material has eroded to said depth and the change in resistance produces a measurable signal indicating that the bearing material has worn to the predetermined extent.

3. A bearing as claimed in claim 2 wherein the conductors are mounted in a non-conducting matrix to form a unit which is located in a blind hole in the bearing material.

4. A bearing as claimed in claim 3 wherein the blind hole is perpendicular to the free surface of the bearing material.

5. A bearing as claimed in claim 1 wherein the wear detector includes a means of generating a beam of radiation and monitors the beam, the arrangement being such that the beam is interrupted once the bearing material has eroded to said depth and the interruption of the beam produces a measurable signal indicating that the bearing material has worn to the predetermined extent.

6. A bearing as claimed in claim 5 wherein the wear detector comprises :

(i) a means of emitting a suitable form of radiation essentially in a single direction,

(ii) a means of detecting said radiation, the detecting means being shielded so that there is no direct line of sight to the emitting means,

(iii) an essentially flat surface spaced a short distance away from the emitting means and the detecting means and capable of reflecting, or absorbing and re-radiating, said radiation from the emitting means and towards the detecting means, and

(iv) a means of recording whether said detecting means is, or is not, registering the presence of said radiation incident upon it.

7. A bearing as claimed in claim 6 wherein the emitting means and the detecting means are mounted in a matrix to form a unit which is located in a blind hole in the bearing material, the blind end of the hole constituting the essentially flat surface.

8. A bearing as claimed in claim 7 wherein

the blind hole is made from the reverse side of the bearing material towards the free surface of the bearing material such that the blind end of the hole is at a predetermined distance from, and approximately parallel to, said wearing surface.

9. A bearing as claimed in claim 7 or 8 wherein the blind hole is perpendicular to the free surface of the bearing material.

10. A bearing as claimed in any one of the preceding claims which includes a plurality of weardown detectors with each detector located at a different depth so that it is possible to monitor progressively the rate of wear of the bearing material.

11. A bearing as claimed in claim 1 substantially as hereinbefore described with reference to, and as illustrated in, Figure 4 or Figures 5a and 5b, or any one of Figures 6 to 11 of the accompanying drawings.

12. A bearing as claimed in any one of the preceding claims wherein the moving member is a propellor shaft of a ship.

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